power

The Upper Waitaki Hydro Power Development

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The mighty Waitaki River, which has already been harnessed in its central regions for hydro electric generation, is sourced by three lakes — Lakes Tekapo, Pukaki and Ohau. All three lie in one of New Zealand's most interesting areas — the Mackenzie Basin.

It is these river sources that the ambitious Upper Waitaki Power Development Project is based on.

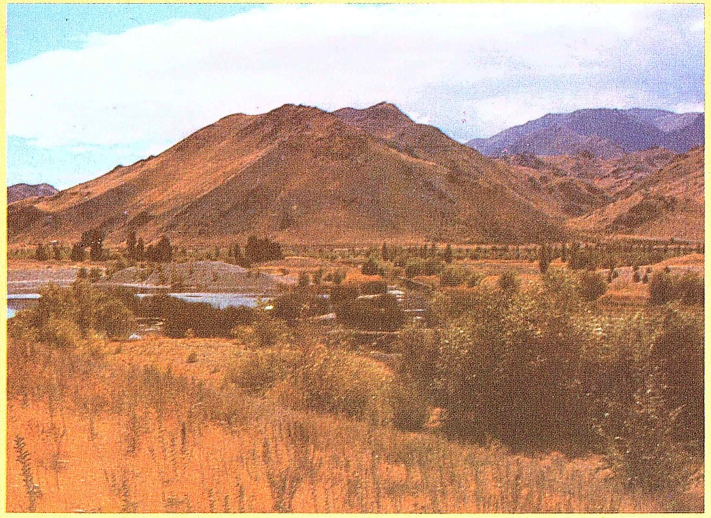
Tucked beneath the majestic Southern Alps, the Mackenzie Country of South Canterbury has a fascinating history of struggles by the early settlers to carve a way of life from the bleak land — around which the legend of the infamous sheep stealer Mackenzie (and his dog) has grown.

The plan to link the three lakes in the Mackenzie Basin to produce electricity has a history which stems from the 1920's. It was then that the first steps to take power from the Waitaki River were investigated and they found form in the construction of the Waitaki Dam and power station in 1928.

The construction of this dam saw the last of the pick and wheelbarrow brigade and gave way to the massive earth-moving machinery we see today.

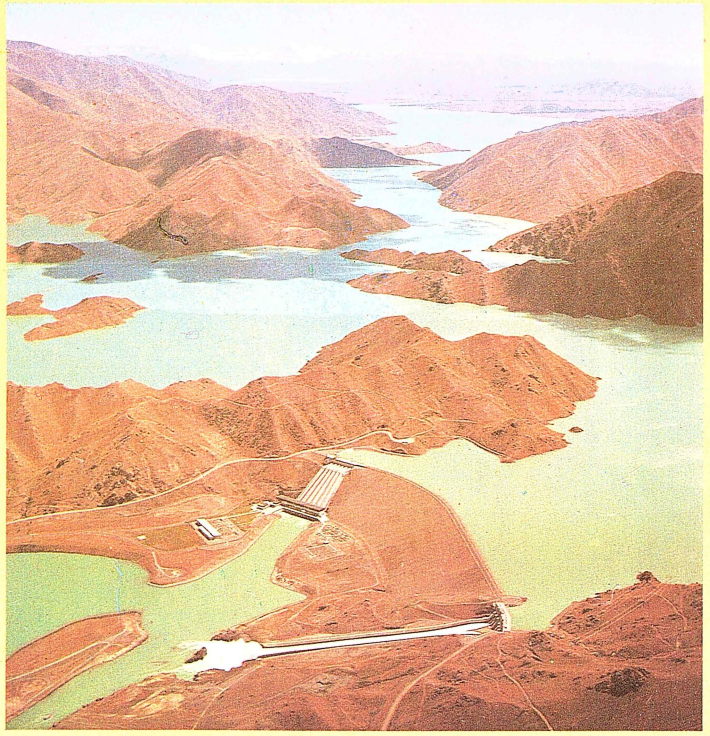
This was the first step in a chain of hydro electric stations on that section of the river. Further planning and investigations were carried out and this culminated in the construction of the Benmore Dam and later, Aviemore. The next step, was the planning and construction of the Upper Waitaki Power Development Project.

The project links the three lakes to one another to utilise the water further before it is passed on to the already established dams at Benmore, Aviemore and Waitaki. To do this required the construction of giant canals to channel the water through four power stations which will produce a total generating capacity of 848,000 kW for the increasing demands of the New Zealand consumer.



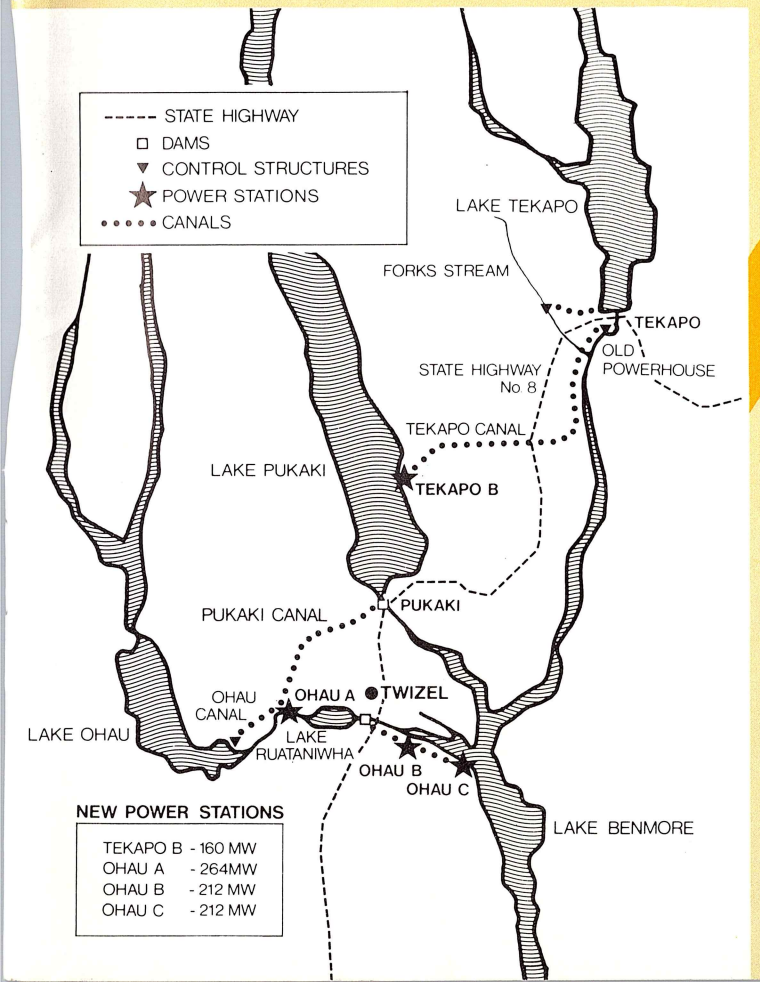
Wildlife Habitat.

Waitaki Dam.



Mighty Benmore.

Water use for the sole purpose of electricity generation is a thing of the past. The design of power projects today incorporates additional benefits such as flood control, irrigation and recreation. In these days of energy conservation, the most efficient use of a resource is upper-most in the designers' minds. In the provision of additional storage by the construction of the Pukaki Dam, more efficient use is made of the Benmore, Aviemore and Waitaki Dams. They will develop additional generation capacity in excess of 400 million kWh, while on a national basis, the extra flexibility in water storage will enable North Island hydro lakes to increase their annual energy output.
But these benefits will not be fully felt until the last power station on the Upper Waitaki Power Project is completed in the mid-1980's.



Aviemore.

Tekapo B

The Tekapo Canal

Lake Tekapo was unharnessed for power generation until 1951 and now has two outlets — one natural but controlled by man and the other, man-made.

The Tekapo A power station, completed in 1951, draws water through a 1.6 km tunnel from the lake, while gates beneath the main highway bridge in the town regulate the flows down the natural water path. The outflow from Tekapo A re-entered the river and flowed on to Benmore.

The Upper Waitaki Power Project has altered all that. The outflows from the old powerhouse now enter the Tekapo Canal and are led away from the Tekapo River valley south-west towards Lake Pukaki. This flow at times would be insufficient to produce the desired amount of generation from the Tekapo B power station at the other end of the canal, so the flow is supplemented by water diverted from the Tekapo River.

To do this, a concrete diversion weir was constructed, 18 m high and 102 m long across the Tekapo River. This ponds the river and when the sluice gate incorporated in the structure is opened, the river flow is diverted into the canal.

Should the gate be closed, or the river in such flood that the canal is unable to contain the flow, the water will cascade over the top of the weir on the downstream side and pass on to Lake Benmore, just as it did in the past.

Water in the canal flows at a leisurely walking pace along the flat bottomed waterway. The inclined walls create an area which would enable one of the inter-island ferries to be floated in it. The canal has a flow capacity of 120 cumecs — about seven million litres a minute. Over its 25 km length, it has a total fall of only three metres and this called for precise surveying to achieve the desired constant gradient of 1:8500.

To create the canal, more than 30 million cubic metres (53 million tonnes) of earth were moved to utilise the natural topography to advantage where at all possible. Depending on the contour of the land, the canal either sits at the original ground level, cleaves through high ground, sidles around a hillside or sits within gravel shoulders raised from the surrounding natural terrain.

Tekapo A.

Winter Construction at Pukaki end of canal.

The construction materials were won — with minor exceptions — from the nearby countryside. It is not lined with concrete, bitumen or a manufactured substance, but by a natural waterproof layer of compacted clay gravels. Seepage through this material is minimal and under test conditions during the summer, more water was lost through evaporation than through ground loss.

Fine sedimentary material is contained in the lake water which passes down the canal and particularly during the first six months use, the flowing water picked up some loose material from the canal walls. If this material was left in suspension, it would quickly abrade expensive seals in the turbine chamber of the Tekapo B powerhouse.

To counter this, the canal terminates in a wide settling pond finished in the same materials as the basic canal itself. This pond was designed to allow the material in the canal flows to be deposited on the bottom, allowing the cleansed water to pass on to the power station, situated on the eastern shore of Lake Pukaki.

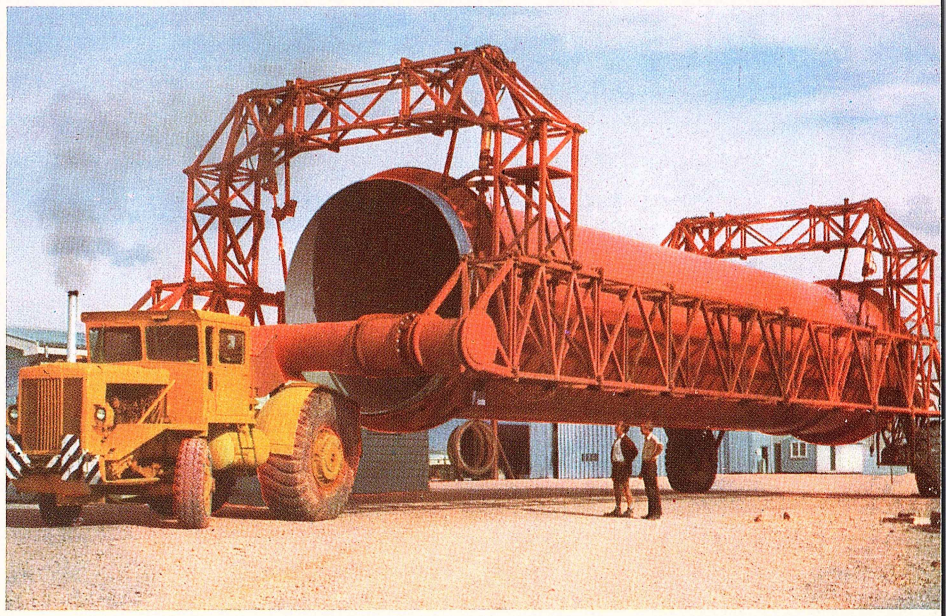
The Penstocks

A sturdy concrete structure carries the water from the canal's settling pond into two penstocks extending 1280 m down the Pukaki lakeside slope to the first of the scheme powerhouses — Tekapo B.

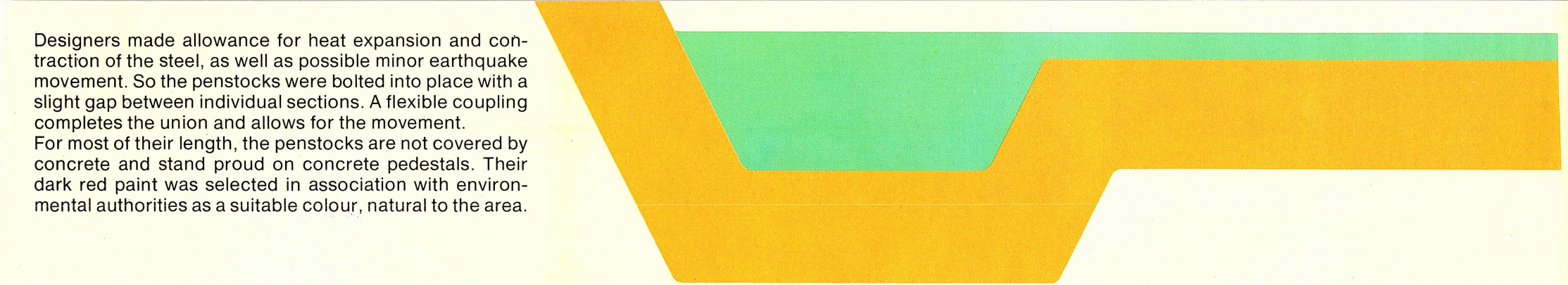
More than 5000 tonnes of steel plate were imported from Japan for the penstocks. Both mild and medium tensile steel was used, with the plate varying in thickness from 12 mm to 29 mm. In all, 104 sections of penstock with a constant diameter of 4.3 m were constructed. Depending on the plate thickness, these sections weighed from 35 to 55 tonnes.

Penstock sections were constructed in 21 m lengths. About a third were made in Christchurch, but the remainder were made in the $1 million factory complex situated in the industrial area in Twizel township. At this factory, all sections were pressure tested, shot-blasted and then painted before being transported 24 km to the site by transporter on public roads.

Canal line from Tekapo.



Designers made allowance for heat expansion and contraction of the steel, as well as possible minor earthquake movement. So the penstocks were bolted into place with a slight gap between individual sections. A flexible coupling completes the union and allows for the movement.
For most of their length, the penstocks are not covered by concrete and stand proud on concrete pedestals. Their dark red paint was selected in association with environmental authorities as a suitable colour, natural to the area.



Penstock slope.

Tekapo B Powerhouse

Located 6 km by road along the eastern lake shoreline from State Highway 8, the Tekapo B powerhouse can be clearly seen by those travelling on State Highway 80 to Mount Cook on the opposite shore of Lake Pukaki. It was set back in a large hillside excavation to keep the length of the penstocks to an economic minimum and this necessitated the removal of 750,000 cubic metres of spoil.

Bedrock was found to be 1,600 metres underneath glacial spoil, too far away for foundations for the 46 m high powerhouse. Instead, hefty concrete raft foundations were poured and the powerhouse — as tall as a 14 storey building — was constructed on these. Structurally, the building contains more than 38,000 cubic metres of concrete and is clad externally with pre-cast concrete slabs faced with inset brick tiles. The roof is steel.

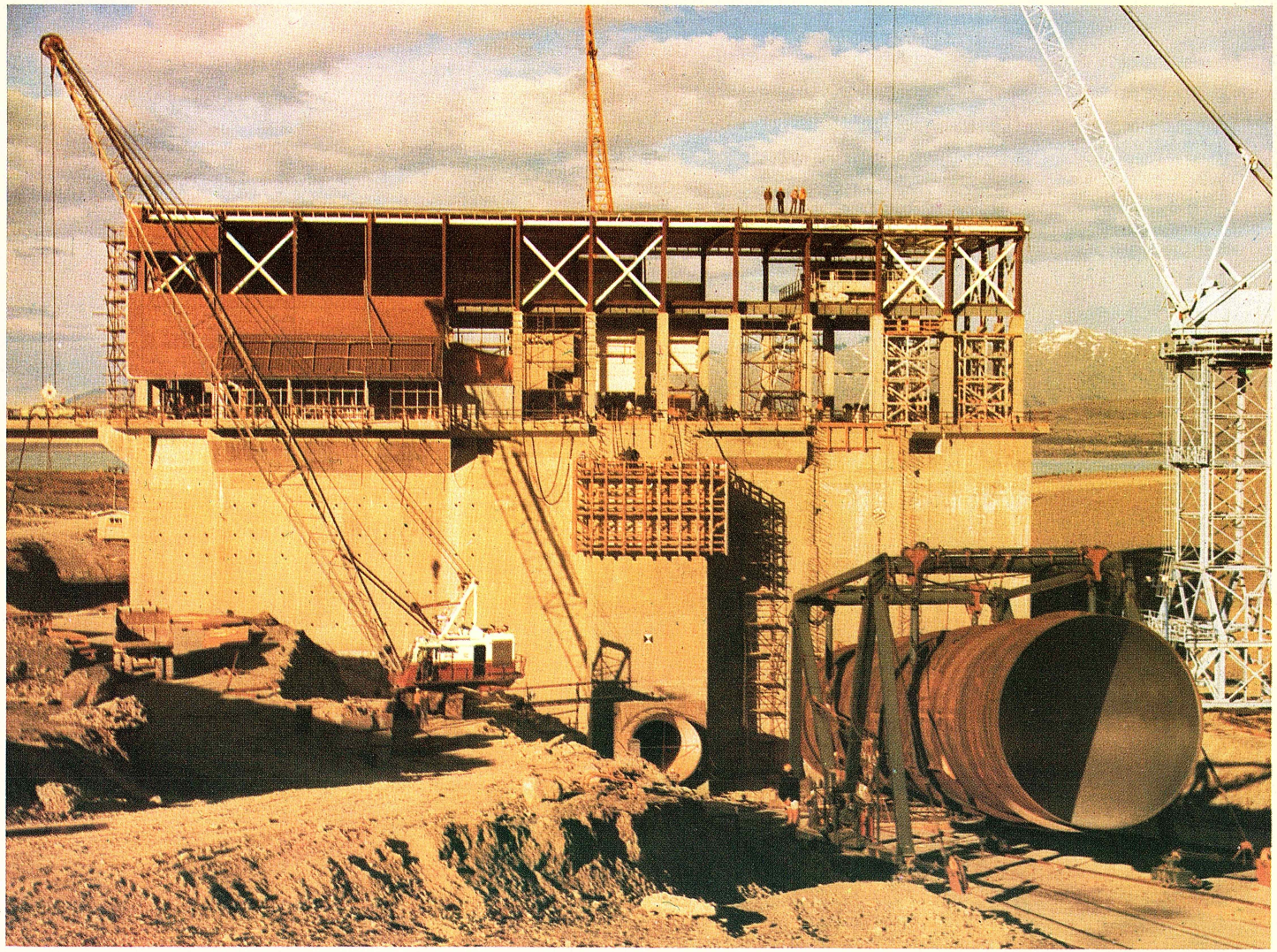
The powerhouse was built in three sections — two containing a turbine and generator each and the third containing the unloading bay used for the initial assembly of the generating equipment and its subsequent maintenance.

Dominion Engineering Co Ltd of Quebec, Canada, manufactured the two turbines. The $1.5 million tender was formally accepted by the New Zealand Government on February 14, 1972. A New Zealand company, GEC (New Zealand) Ltd, won the tender for the supply of two 80 MW generators, at a cost of $1.7 million.

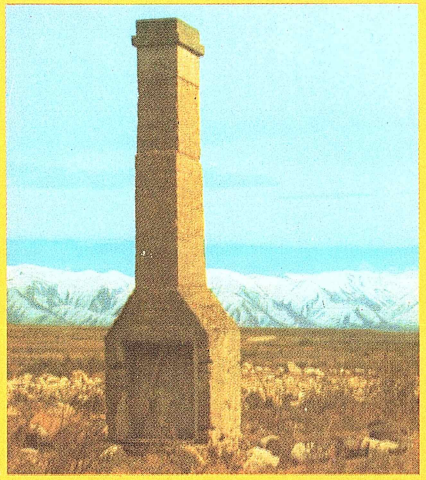
At full capacity, Tekapo B produces 160,000 kW.

Tekapo B is unique in New Zealand, because it is a power station wholly surrounded by water. It was constructed on dry land, but designed to operate as an island when Lake Pukaki (into which it discharges) was raised. The only visible connection with the shore is a 75 m long bridge. Even the penstocks vanish beneath water as they near the powerhouse.

The station was the first of the four on the Upper Waitaki to be commissioned.



Lake Pukaki Dam



Remains Pukaki Hotel (built 1880's).

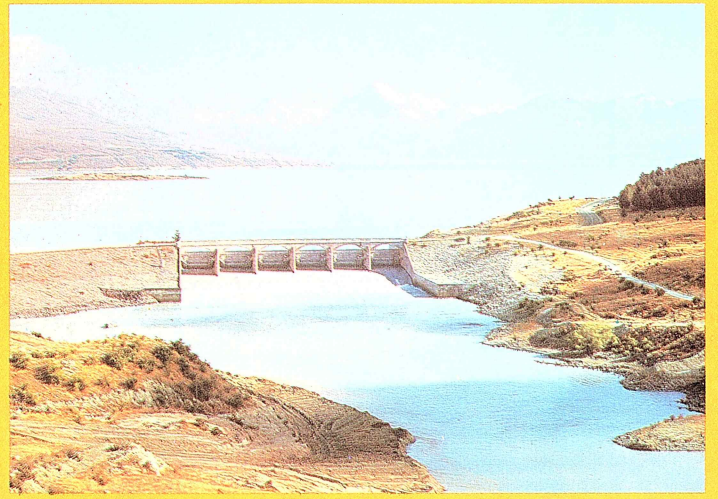
The Lake

Some 20 years before work started on the Upper Waitaki Project, the Ministry of Works and Development had already raised Lake Pukaki to provide water storage for the power stations constructed or planned in the middle reaches of the Waitaki River. It was raised 9 m then, but the construction of the storage dam for the Upper Waitaki has raised the lake a further 37 m, which has effectively doubled the lake's capacity.

In many ways, the raising of Lake Pukaki could be regarded as the heart of the Upper Waitaki project. About 40 percent of the Waitaki River flow is sourced in Lake Pukaki. The volume of water entering the lake reaches a peak in the spring — summer thaw. The previous characteristics of the lake did not allow for much of this to be retained for later use.

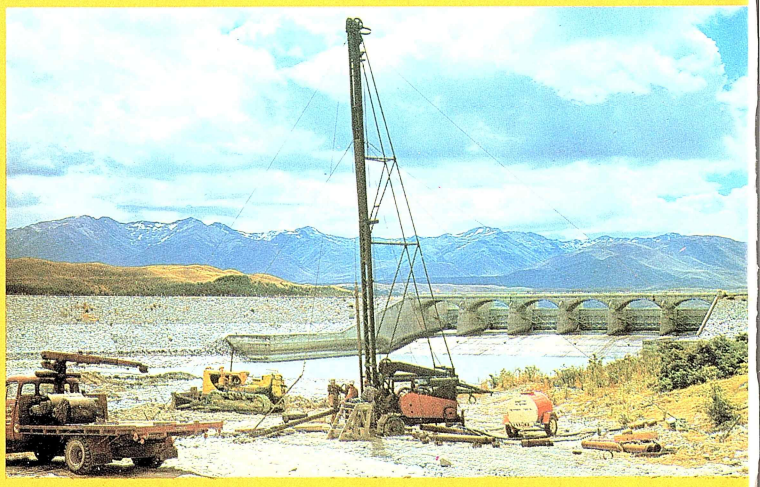
Behind the new dam, the high inflows coincide with the minimum demand period, and can then be used during the winter heavy demand. In this way, prudent management of the available water resource and favourable weather should result in the lake being brim-full at the end of the summer and at its lowest just before the thaw.

Surface area of the lake was increased from 11,140 hectares to 17,680 hectares. The shoreline increased in length from 60 km to 81 km and its maximum depth from 71.5 m to 108.m.



Original control structure.

High dam investigations.



Pukaki dam construction.

Dam Structure

Basically, the dam consists of two major components, as is true for the majority of earth dams.

The impervious, or watertight, section is in the central dam core and is made up of silty gravels taken largely from terminal moraine of an ancient glacier near to the dam site. More than three million cubic metres of the material was used on the core and the blanket.

There is no great inherent strength in this on its own and so it is supported both on the upstream and downstream faces by substantial shoulders of gravel. The 3 million cubic metres of shoulder material was won from the Pukaki River valley.

Like other structures in the Upper Waitaki Project, the dam sits on top of materials of glacial origin — particularly gravels, silts and sands. Because of the absence of bedrock and the permeable nature of the foundation, the dam's structure incorporates a section designed to minimise seepage. This is a silt blanket which extends 300 m upstream of the dam centreline.

There are drainage zones to control seepage and filters of processed gravels and sands to prevent migration of the earth components from one zone to another in other sections of the dam.

Fortunately, the core, shoulder and blanket materials were all available within 3.5 km of the dam site.

Material Selection, Pukaki Dam.

Diversion Culvert

To enable the dam construction to be carried out on a dry foundation, a culvert containing 36,700 cubic metres of concrete was built to take the outflow of Lake Pukaki while the dam was built above it. It was an elliptical (for strength) cross section 10 m high and 6 m wide extending for 360 m through the dam. If required, it could channel more than 34 million litres of water a minute from the lake.

A gate chamber was built into the culvert so that outflows could be regulated during the raising of the lake. This was done using a 76 tonne steel radial gate 9 m high and 6 m wide. The gate was designed to withstand the greatest water pressure of any radial gate in New Zealand as under full load it would be 57 m below the level of the new lake. It is able to withstand a total water load in excess of 3,500 tonnes.

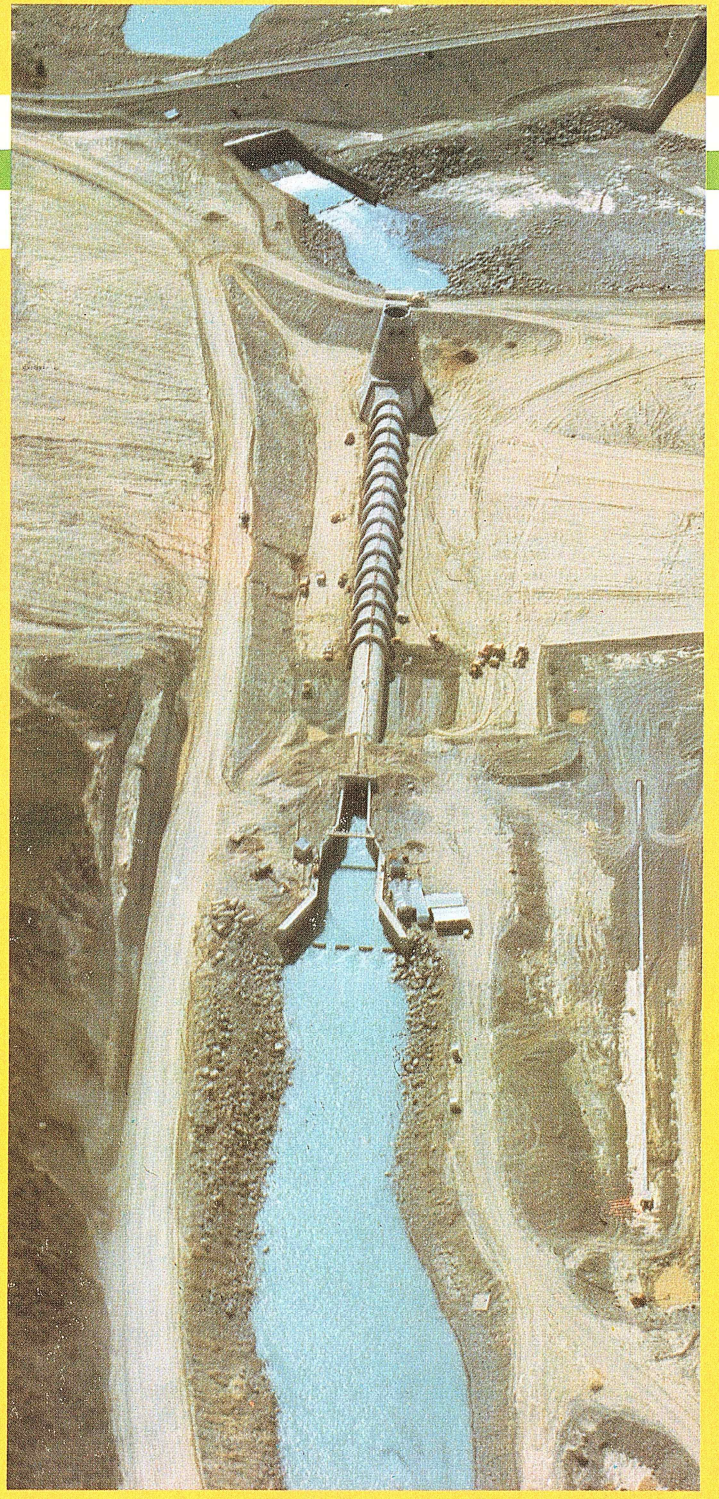
Spillway

The next stage on the project involves the diversion of Lake Pukaki's normal outflow into a canal. As this canal can only carry a fixed volume, an alternative exit is required for use in the event of floods striking while the lake's storage is full, otherwise the dam would be over-topped and washed away.

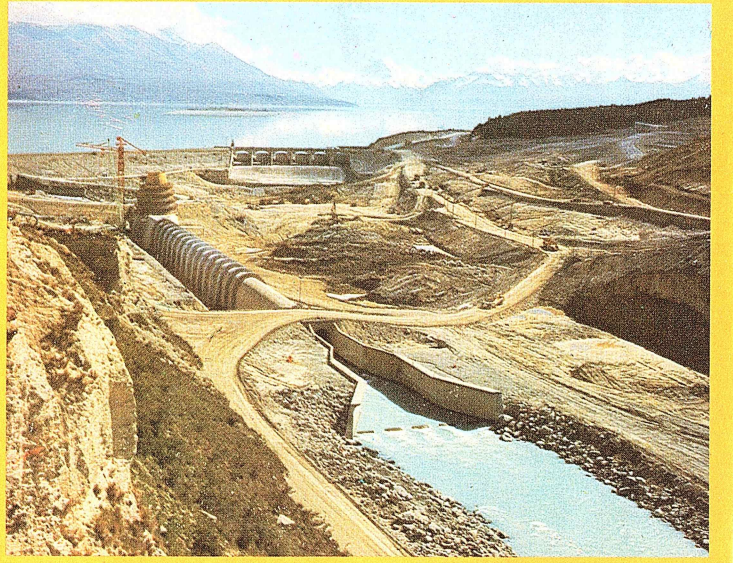
The Tasman River at the head of Lake Pukaki provides for more than 40 percent of the Waitaki River's flow and historically, some devastating floods have been recorded from the lake.

The safety valve is a concrete spillway 450 m in length, adjacent to the eastern side of the dam. It was designed to pass floods equivalent to more than 204 million litres a minute. The spillway was excavated to shape by project forces and structural concrete was laid by Downer and Co Ltd.

In effect, it is a walled chute 50 m wide and dispels energy from the falling water before it re-enters the Pukaki River bed. This is effected by opening the downstream end of the spillway into a terraced bowl with concrete teeth up to 6 m high jutting from its base.



Pukaki canal inlet.



Canal inlet structure.

Nearly completed (spillway on right).

Ohau A Power Station

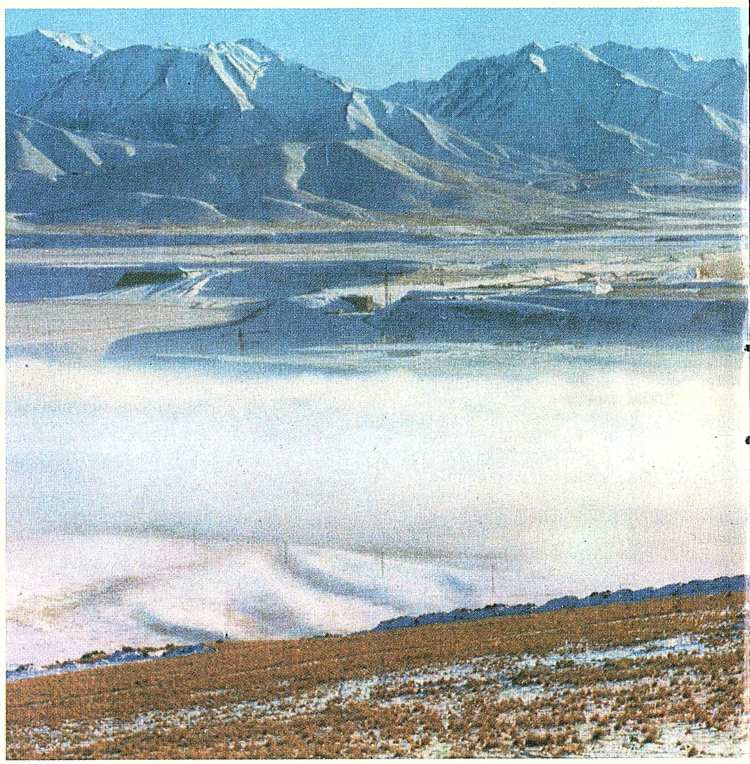
Pukaki Canal

It should be remembered that no power is generated at the Pukaki Dam site. Instead, the water energy is utilised at Ohau A powerhouse to the south of Twizel township.

Into the western wing of the Pukaki Dam, the designers incorporated a canal inlet structure to channel water from the raised lake into the Pukaki Canal for a 13 km journey to the powerhouse.

Although shorter in length than the Tekapo Canal, this structure to Ohau A powerhouse has nearly four times the Tekapo Canal flow. This is because it is passing both the outflow from Lake Tekapo and Lake Pukaki.

It is large enough to float two of the inter-island ferries side-by-side and can pass 440 cumecs (27 million litres a minute) of water. From berm to berm, it measures 84 m, with a distance across the water surface of 71 m. The water depth is 10 m, and the canal overall has a depth of 12 m.



High drilling site overlooking Ohau River.

The flow rate is the same as Tekapo Canal, so scour problems and friction losses are minimised. The gradient is more gradual, falling only 1.05 m from end to end — a gradient of 1:12,000.

Local deposits, geologically known as Balmoral Outwash Gravels, were used to form the canal embankment profile. These materials were pushed out ahead of the glaciers which levelled the Mackenzie Basin millions of years ago.

Within the embankment, the canal is lined with even older materials — the pre-Balmoral Outwash Gravels. These are more weathered, have a higher clay content and make up the water-proofing layer.

Unlike Tekapo B, Ohau A does not have a settling basin at the terminal of the canal, so other measures were necessary to stop particles being scoured from the canal walls and damaging the turbine seals in the powerhouse. An armour layer of gravels was placed between the canal lining and the flowing water.

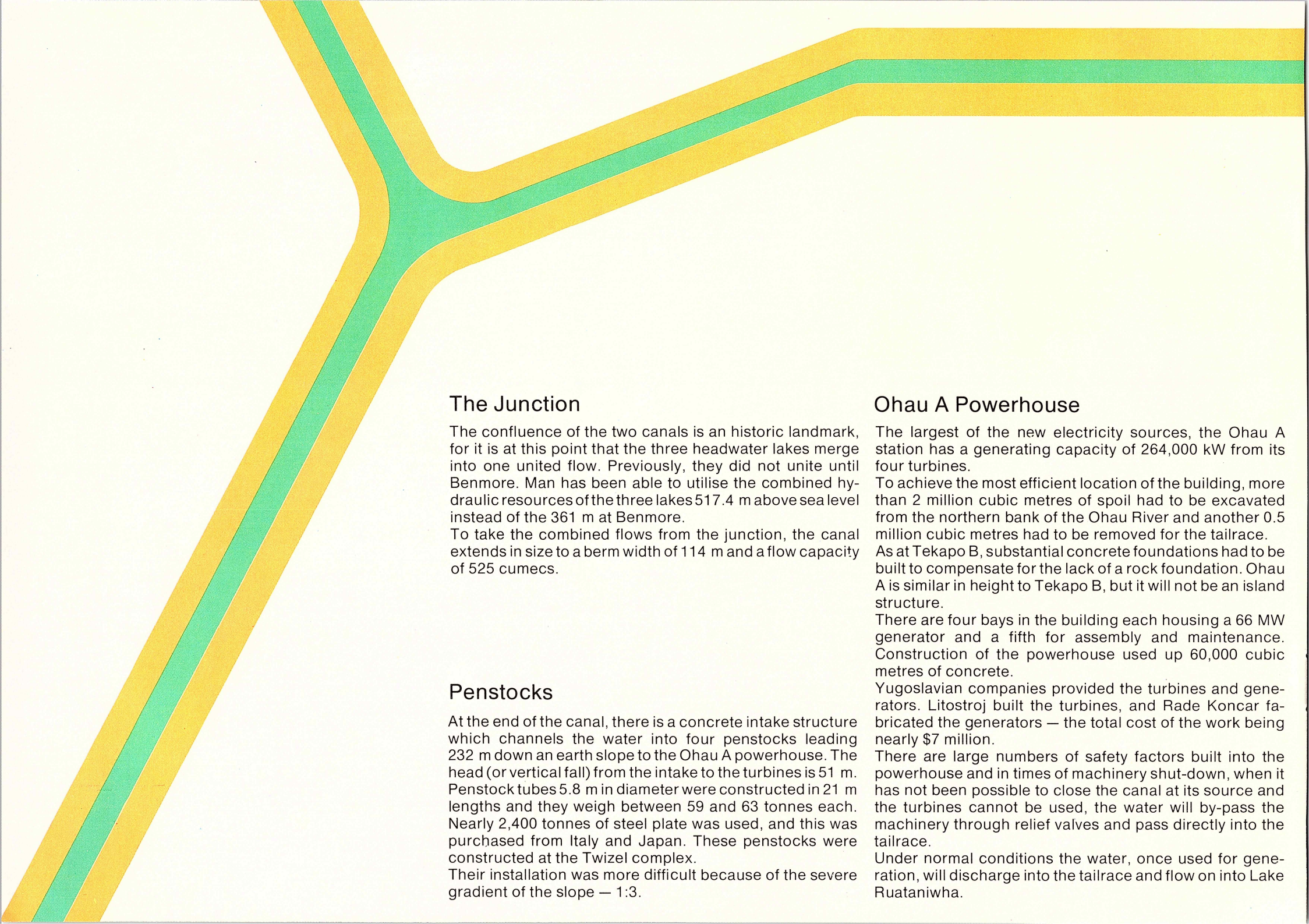
Ohau Canal

Just before the Pukaki Canal meets the intake structure to Ohau A penstocks, it is joined by the Ohau Canal.

This canal brings the outflow from the third headwater lake — Lake Ohau — to join the waters of lakes Tekapo and Pukaki in the Pukaki Canal. Until the advent of the Upper Waitaki Project, flows from Lake Ohau passed naturally down the Ohau River. However, a concrete weir now spans the river inlet, diverting normal flows into the canal. Floods will spill over the weir and flow down the river as in the past. Lake Ohau will remain much at its natural levels.

The Ohau Canal is constructed in a similar manner to the Pukaki Canal, but having smaller flows, is logically smaller. It was designed to pass 170 cumecs (10 million litres of water a minute) and has a berm width of 63.5 m, water surface width of 45.5 m and a depth of 5.75 m. The flow rate is the same as the other canals but it has a slightly more pronounced gradient of 1:5880 with a total fall from end to end of 1.4 m.

Lake Ohau.



The Junction

The confluence of the two canals is an historic landmark, for it is at this point that the three headwater lakes merge into one united flow. Previously, they did not unite until Benmore. Man has been able to utilise the combined hydraulic resources of the three lakes 517.4 m above sea level instead of the 361 m at Benmore.

To take the combined flows from the junction, the canal extends in size to a berm width of 114 m and a flow capacity of 525 cumecs.

Penstocks

At the end of the canal, there is a concrete intake structure which channels the water into four penstocks leading 232 m down an earth slope to the Ohau A powerhouse. The head (or vertical fall) from the intake to the turbines is 51 m. Penstock tubes 5.8 m in diameter were constructed in 21 m lengths and they weigh between 59 and 63 tonnes each. Nearly 2,400 tonnes of steel plate was used, and this was purchased from Italy and Japan. These penstocks were constructed at the Twizel complex.

Their installation was more difficult because of the severe gradient of the slope — 1:3.

Ohau A Powerhouse

The largest of the new electricity sources, the Ohau A station has a generating capacity of 264,000 kW from its four turbines.

To achieve the most efficient location of the building, more than 2 million cubic metres of spoil had to be excavated from the northern bank of the Ohau River and another 0.5 million cubic metres had to be removed for the tailrace.

As at Tekapo B, substantial concrete foundations had to be built to compensate for the lack of a rock foundation. Ohau A is similar in height to Tekapo B, but it will not be an island structure.

There are four bays in the building each housing a 66 MW generator and a fifth for assembly and maintenance. Construction of the powerhouse used up 60,000 cubic metres of concrete.

Yugoslavian companies provided the turbines and generators. Litostroj built the turbines, and Rade Koncar fabricated the generators — the total cost of the work being nearly $7 million.

There are large numbers of safety factors built into the powerhouse and in times of machinery shut-down, when it has not been possible to close the canal at its source and the turbines cannot be used, the water will by-pass the machinery through relief valves and pass directly into the tailrace.

Under normal conditions the water, once used for generation, will discharge into the tailrace and flow on into Lake Ruataniwha.

Lake Site.

Blasting for diversion.

Lake Ruataniwha

There will be a new lake in the Waitaki Basin when water flows from Ohau A. It will be small in comparison to others in the region — only some 343 hectares — but it is being treated as a major recreational asset.
Provision has been made for specially designed beaches, boat launching ramps, wildlife habitats and the development of a specially co-ordinated lakeshore environment.
Project forces have created a camping ground close to the lake which is already proving popular. With modern amenities, the camp can be regarded as a prime asset to the region.

Ruataniwha Dam

To form the lake, a 640 m long dam following the curvature of the river flats is being built across the Ohau River. It will carry State Highway 8 on its crest, one kilometre south of Twizel township.
Like Pukaki dam, it is constructed of earth materials involving the clay silts with upstream and downstream gravel shoulders. It contains about 0.8 million cubic metres of material, most of which was available close to the dam site.
The dam has a base width of 180 m which tapers 13 m at the crest. It is 36 m high.
Before construction could start, the Ohau River had to be diverted. A channel was carved through a low rocky extension of the Benmore Range and was faced with concrete. A double-tiered structure was incorporated with three diversion sluice gates at the lower level to take river flows during construction. The gates are each 9 m wide and 6 m high.
On completion of the dam, the diversion gates are closed and the structure employed as a spillway. Unlike spillways on the other dams on the Waitaki, there are no control gates on the Ruataniwha spillway.
Should the level of Lake Ruataniwha rise 0.5 m above normal, then the waters will merely flow over the spillway and down the old Ohau River valley. If the Ohau was in full flood, the spillway could pass 104 million litres of water a minute.
In effect, the water course serving as a river diversion chamber during dam construction will double as a spillway for the completed dam.
There is a natural gap on the southern side of the dam and the interrupted dam faces curve downstream in unison, creating a canal inlet. The outflow from Lake Ruataniwha passes through this gap and onto the next canal leading to the Ohau B power station.

Ohau B and C

The combined headwaters of the Waitaki River flow from Lake Ruataniwha to the Ohau B power station, some 2.5 km downstream from the dam structure. With four turbines and generators, this station at peak will produce 212,000 kW.
To complete the journey, the outflow from Ohau B passes by canal to the final link in the chain, Ohau C.
This latter station is located virtually on the shore of Lake Benmore, and is of identical design to Ohau B, having four turbines and a generating peak of 212,000 kW. At this stage the Upper Waitaki Scheme merges with the existing power stations of Benmore, Aviemore and Waitaki.

Twizel

It would be hard to imagine that over a decade ago, there was no such town in the Mackenzie Basin called Twizel.

As recently as 1968, the town site was typical New Zealand sheep run property, populated by sheep and the odd rabbit.

Yet within a few years a whole new community was created and the town reached its maximum population of almost 6,000 in its sixth year.

All these latter-day settlers came with a single intention — either directly or indirectly, to get the Upper Waitaki Power Project built. Twizel was designed as but another element of the programme.

It is the residential base for the project workforce, administration and construction headquarters of the largest hydro-electric undertaking in New Zealand history.

Twizel is a distinctive name — taken from the Twizel River which flows close by. In earlier days, the river was named by one John Turnbull Thompson, who saw in the locality a resemblance to his Northumberland birthplace. There, the Twizel Bridge is an historic landmark spanning the River Till.

Thompson was the first surveyor-general of New Zealand.

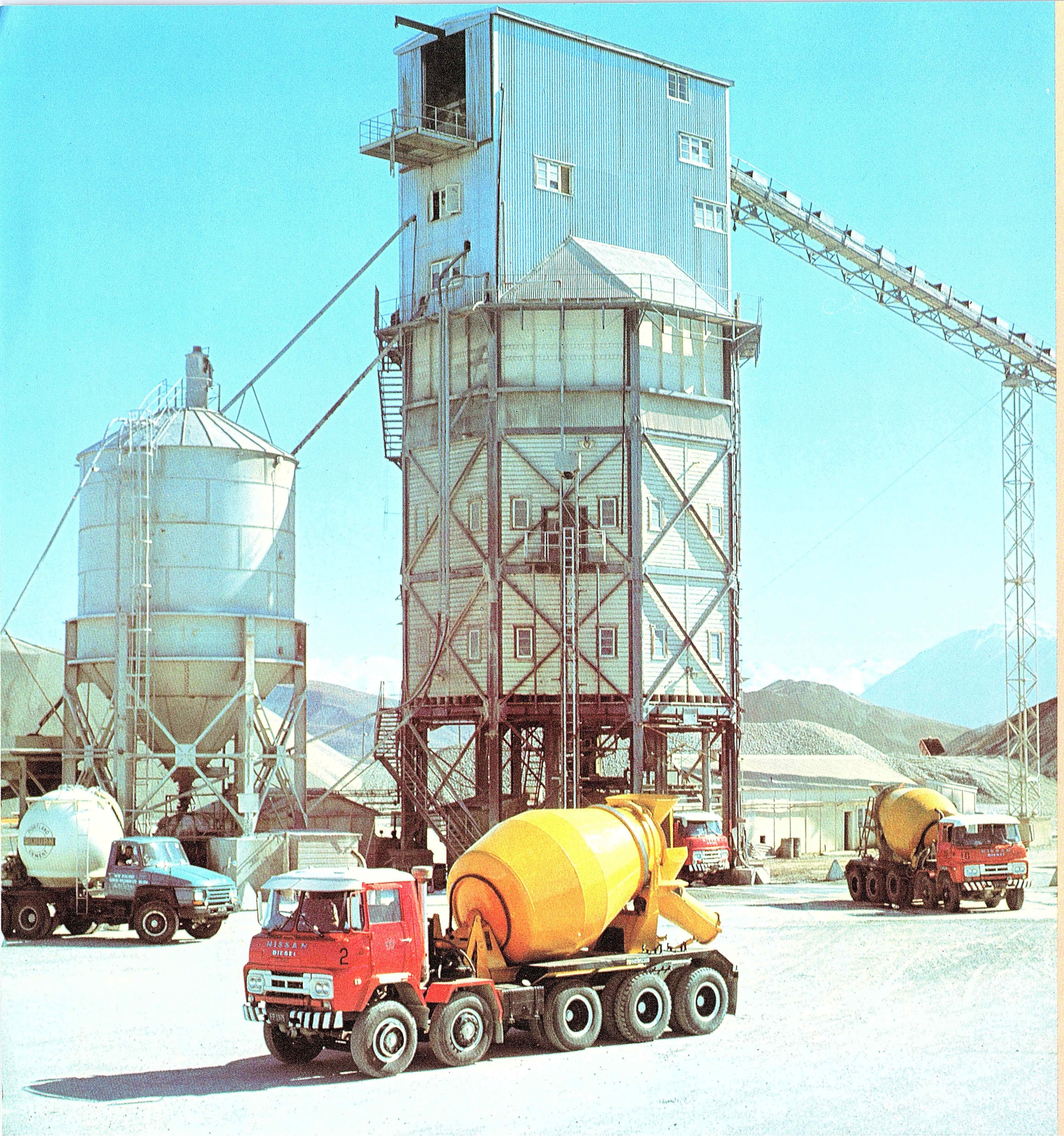
The township stands on part of the Ruataniwha Station, which was purchased by the government for just that purpose in 1965.

Remnants of the station are still farmed by the Lands and Survey Department on behalf of the New Zealand Electricity Department. The town might not be located in the geographic centre of the Upper Waitaki Project, but 85 percent of the total earthworks and concrete placement is done within 10 km of the town.

Otematata, the construction base for the Benmore and Aviemore Projects, became a base for the establishment of Twizel. A house building production line was established there by the Ministry of Works and Development, and 500 houses were built. The remainder were let for tender and

were constructed by contractors from Invercargill to Christchurch.
On the site, oxidation ponds were laid out, a modern water supply with fluoridation prepared and 1300 sections marked out along 24 km of sealed streets. The layout was on a basic Scandinavian concept first used at the North Island Hydro town of Mangakino. It had previously been tried at Otematata and was modified for Twizel.
Being 460 m above sea level and at the toe of the Southern Alps, the site provides a harsher climate than many of the residents had experienced before. It has a climate of extremes. In summer, temperatures frequently climb to the mid-30 degrees Celcius. But in winter, frosts in excess of 10 degrees Celcius are common.
Accordingly the homes were designed to cope with these extremes. Walls, floors and ceilings are insulated.

But unlike other New Zealand towns all land in Twizel is owned by one organisation — the Ministry of Works and Development. Both employer and landlord, the Ministry installed the water supply sewerage system, provided a rubbish collection, street maintenance and other services. Responsibility for cultural and recreational facilities is delegated to the Twizel Community Council — an incorporated society of 18 members elected by residents every two years.
The town has a $300,000 community hall complex, and the facilities are administered by the Community Council. Other activities of the Council include film showings, and the organisation of housie evenings for financial assistance to the many local clubs.
There are more than 90 active organisations catering for sporting, social and cultural activities ranging from golf, squash, car racing, and wine-making to breast feeding, square dancing and bridge.



Construction Equipment

One of the most important items of construction equipment on the upper Waitaki projects is a 107 cu m per hour capacity concrete batching plant. For the five canals, two dams, four power stations, and other smaller structures involved in the projects the plant will produce nearly 2 million tonnes of concrete.

The batching plant has an interesting history. It was purchased by the New Zealand Government at the end of World War II after it had played a major role in the reconstruction of Pearl Harbour, having been rushed out from the United States for the purpose. It has since given sterling service during construction of the Roxburgh, Benmore, and Aviemore dams and power stations.

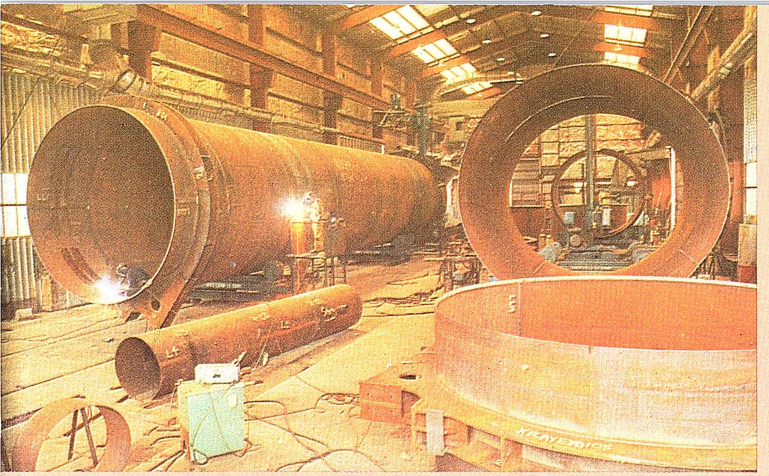
Six sizes of stones and sands are used by the batcher. The required quantity of each is selected from holding piles by electrical remote control and conveyed by belt feed to the top of the 35 m high plant. They are then screened and delivered into hoppers above the mixer floor.

A control panel operator controls the weighing of cement, water, and aggregates according to the particular type of mix required. Four 2-cu yd mixers then receive the ingredients and mix the concrete. When ready this is discharged into a large hopper the base of which protrudes beneath the plant and delivers the mix into waiting vehicles. In full production, the batcher will use 252 tonnes of cement a week.

The largest fleet of earthmoving and other construction equipment ever assembled in New Zealand is required to carry out the upper Waitaki power development.

Included are the biggest dump trucks and loaders in the country — specially imported to enable the various projects to be completed in time to keep apace of the ever-increasing demand for electricity.

Other construction equipment includes mechanical shovels, motor scrapers, bulldozers, cranes, graders, tractors, compaction rollers, and an extensive fleet of trucks and light vehicles.



WID E LOAD

CATERPILLAR

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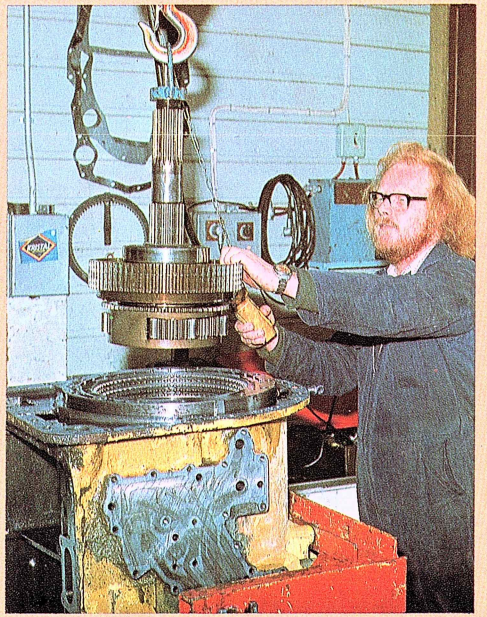
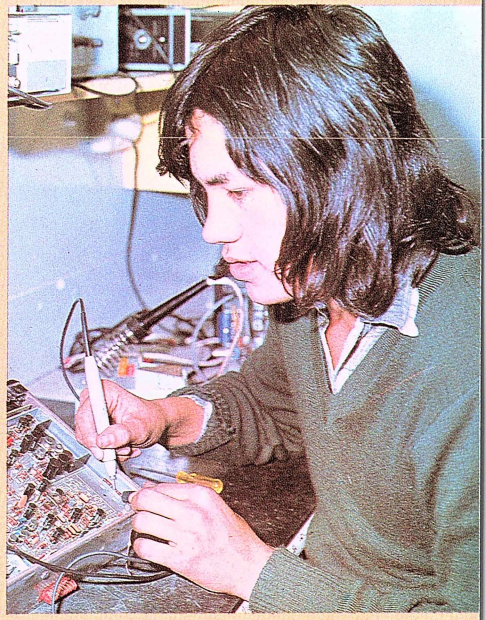




Seismology

The construction of massive structures and the containing of large amounts of water in areas previously untouched in this way has a curious affect on the surrounding land.

The Department of Scientific and Industrial Research Geophysics Division established that the filling of Lake Benmore in 1964 was followed by a sharp increase in the number of "earthquakes" in the area. Within 80 kilometres of the dam, 29 shocks occurred in the six years after the impounding of the water, compared with only four in the 30 months before.

It was this knowledge that lead the division to recommend a full seismic surveillance network around Lake Pukaki. The division was understandably concerned, because Lake Pukaki holds double the amount of water stored in Lake Benmore.

However the type of "earthquake" involved would be more accurately described as micro-earthquakes of a magnitude unlikely to be noticed by residents in the area. Micro-earthquakes would be more like localised creaking of rock. The formation of lakes does not create earthquakes, but rather releases the stresses already existing within the ground.

These would eventually be released even without the construction of a dam and the consequent creation of a larger body of water.

The DSIR, in association with the New Zealand Electricity Department, installed nine seismometer stations in the Upper Waitaki. These contain instruments far more sensitive than normal seismographs, and thus detect far smaller tremors.

The information from the seismometers is relayed by small radio transmitters to a central visible recorder in Twizel and the data analysed by DSIR scientists.

The Environment

The Ministry of Work's landscaping section has a well-established nursery in Twizel, and for several years has been conducting experiments to establish which varieties were most suitable for the area.

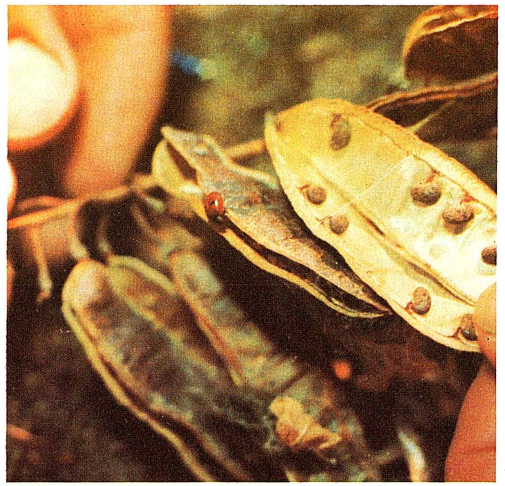
Climatic factors, soil characteristics, manure requirements, and the suitability of various types of plants for the region have all been studied and the information obtained made available to residents so that they also could play their part in beautifying one of New Zealand's newest towns.

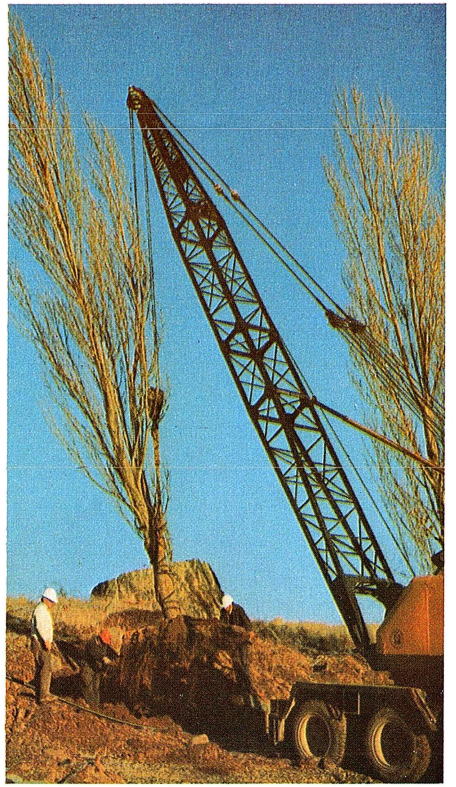
Since work on Benmore started in 1957 the hydro team has planted more than 1 million trees in the Waitaki valley. Those planted in the early years are now well established and provide a welcome relief to the monotony of the previously dry and sparse countryside.

Three factors have been held paramount when planning plantings: the provision of amenities, appearance, and conservation. In planting a particular area a species is selected according to which of these factors is most applicable but with due consideration being given to the others.

Many species have been used. In gullies and valleys poplars and willows have been used extensively, while on faces with a rapid run-off, pines (with their quick growth) and eucalypts (good rooting systems) have been most successful.

Much of the landscaping work has involved restoring scarred areas from which construction materials have been taken. Many such areas have been developed into boat harbours, camping sites, picnic areas, aquatic basins and beaches, thus providing the Waitaki basin with recreation areas which would not otherwise have been possible for many generations.





Tree Planting.

The Upper Waitaki Power Development Project constructed by The Ministry of Works and Development for The New Zealand Electricity Department
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